Localization of the motor cortex on magnetic resonance images by transcranial magnetic stimulation

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Introduction

- ✓ 30% of people with epilepsy do not respond to medication
- ✓ Surgically removing the epileptogenic zone is an option…
- ✓ … provided this area is not responsible for critical functions
- ✓ Evolution to multimodal, non-invasive patient-specific mapping of critical brain regions (MRI, fMRI, MEG, TMS)
- ✓ “Gold” standard for motor cortex mapping is invasive implantation of cortical electrode grid (electrocorticography ECoG)
- ✓ **Navigated transcranial magnetic stimulation (TMS)** offers a non-invasive alternative for cortical mapping

Aim: improve TMS based localization of the motor cortex by including patient-specific electrical field simulations based on the SimNIBS pipeline[1]

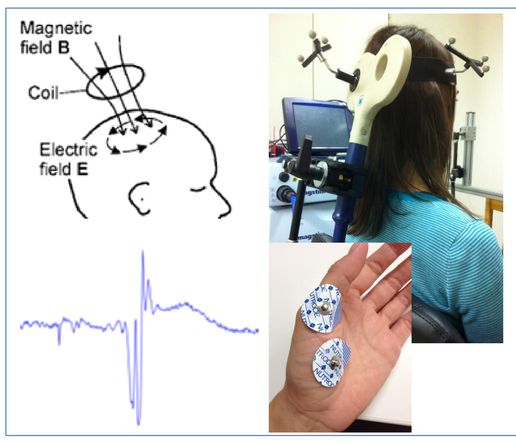
Results

- ✓ TMS simulations feasible using clinical data (3D-T1 & T2)
- ✓ Obtained TMS field map correlates well with ECoG data
- ✓ Validation complicated by the coarse sampling of ECoG

Future perspectives

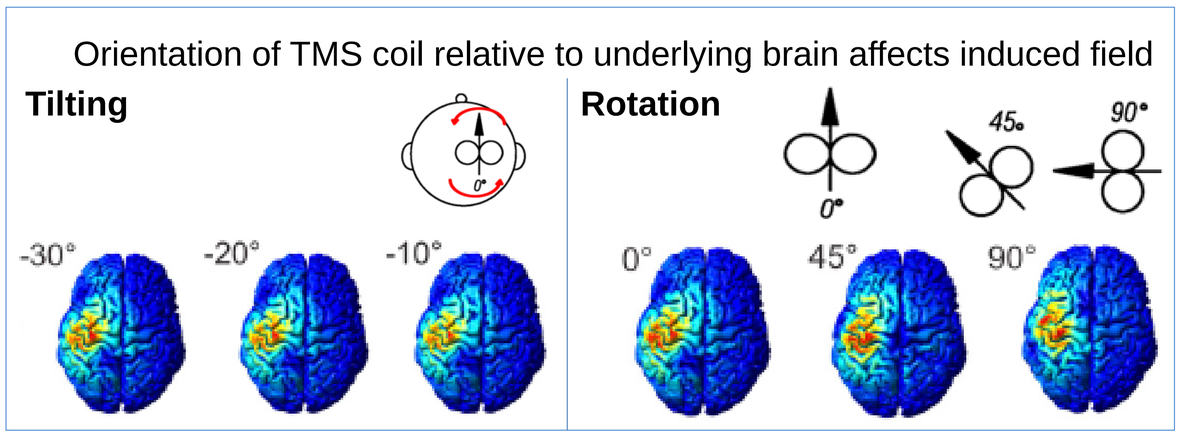
- ✓ Adapt weighting method to combine different electrical field maps
- ✓ Optimize threshold used for localization
- ✓ Further validation in larger patient groups
- ✓ Include brain lesions with different electrical properties
- ✓ Determine potential for use in clinical routine

Current practice: deduce location of motor region from the navigated TMS positions with significant MEP, ignoring patient-specifc anatomy

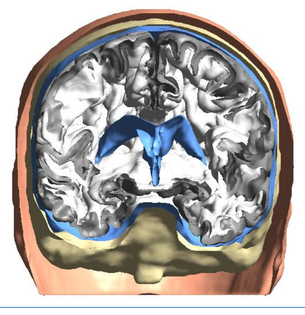


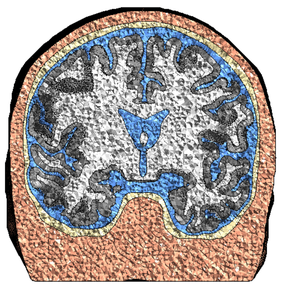
Magnetic field in TMS coil
➔ induces electric field in the brain
➔ neuronal depolarization
If over the motor cortex: MEP
MEP can be measured by EMG in selected hand / foot muscles

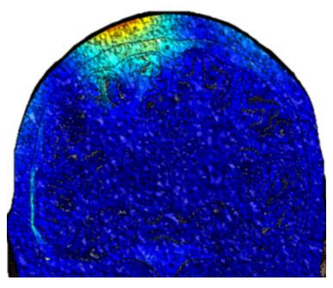
Orientation of TMS coil relative to underlying brain affects induced field



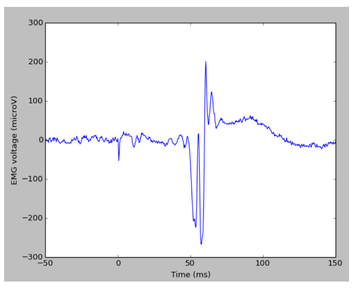
Proposed method: patient MRI used for finite-element based electrical field simulation, weighted average over TMS sites based on EMG recordings

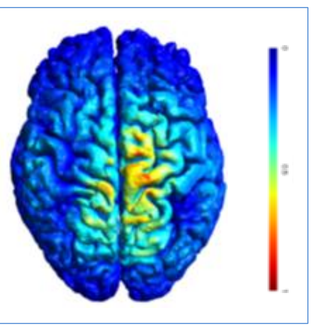






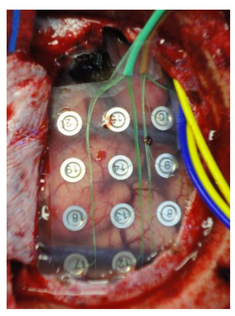
Tissue conductivities	
WM	0.126 S/m
GM	0.276 S/m
CSF	1.654 S/m
Skull	0.010 S/m
Skin	0.465 S/m

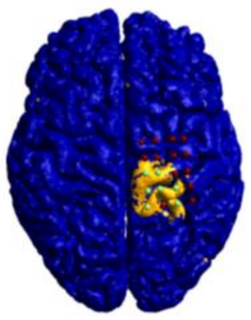




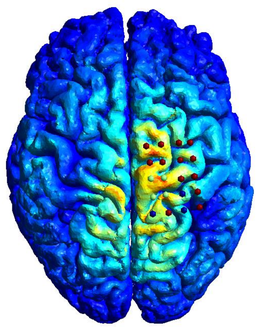
Proof of concept: example of foot mapping (patient 1) & hand mapping (patient 2), compared to ECoG and fMRI

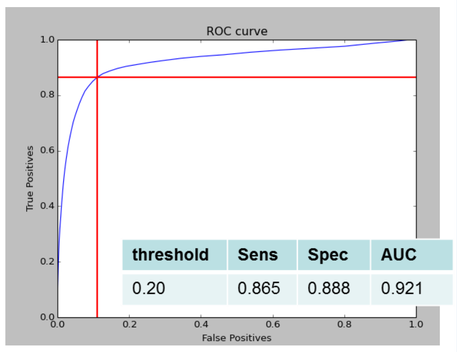
Ground truth — Patient 1





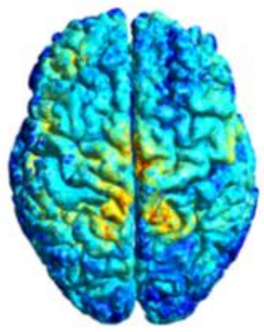
TMS map

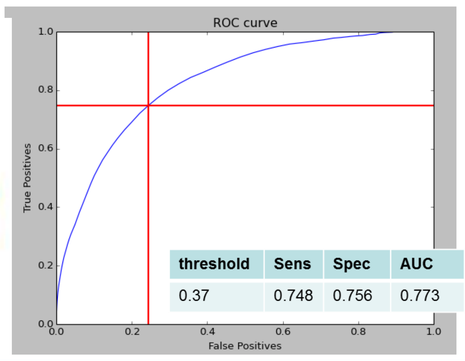




threshold	Sens	Spec	AUC
0.20	0.865	0.888	0.921

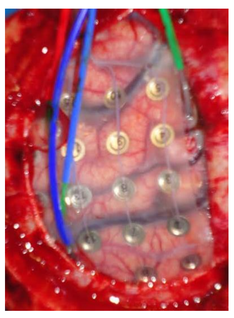
fMRI map (bilateral)

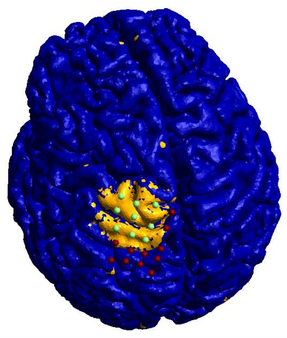




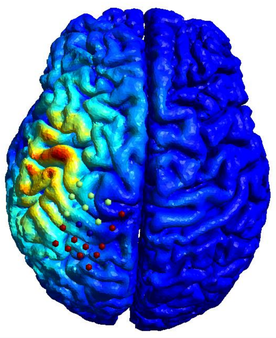
threshold	Sens	Spec	AUC
0.37	0.748	0.756	0.773

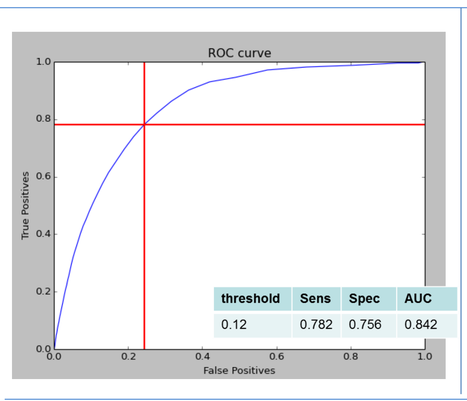
Ground truth — Patient 2





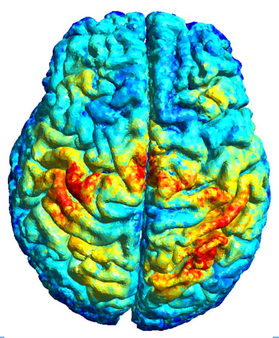
TMS map

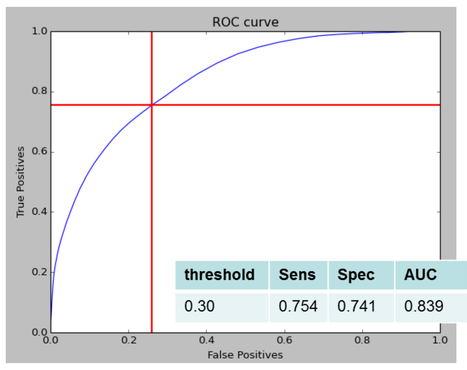




threshold	Sens	Spec	AUC
0.12	0.782	0.756	0.842

fMRI map (bilateral)





threshold	Sens	Spec	AUC
0.30	0.754	0.741	0.839

References [1] Opitz A, Legon W, Rowlands A, Bickel WK, Paulus W, Tyler WJ. Physiological observations validate finite element models for estimating subject-specific electric field distributions induced by transcranial magnetic stimulation of the human motor cortex. NeuroImage; 2013; 81:253–364